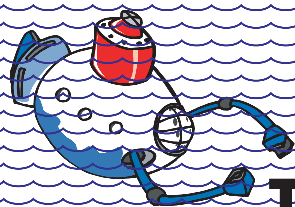

This Old Tubeworm

Focus
Growth rate and age of species in cold-seep communities

Grade Level
9-12 (Life Science)

Focus Question
What effect may conditions in cold-seep communities have upon growth rate and longevity among organisms typical of these communities?

Learning Objectives
Students will be able to explain the process of chemosynthesis.

Students will be able to explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

Students will be able to construct a graphic interpretation of age-specific growth, given data on incremental growth rates of different-sized individuals of the same species.

Students will be able to estimate the age of an individual of a specific size, given information on age-specific growth in individuals of the same species.

Additional Information for Teachers of Deaf Students
In addition to the words listed as key words, the following words should be part of the vocabulary list.
Hydrothermal vent
Hydrogen sulfide
Tectonic plate
Chemosynthetic bacteria
Hydrocarbon gases
Continental margin
Polychaete worm
Salinity
Tubeworm
Poganophora
Tentacles
Hemoglobin
Acidic
Toxic hydrogen sulfide
Methane
Tubeworm
Curvilinear regression

There are no formal signs in American Sign Language for any of these words and many are difficult to lipread. Having the vocabulary list on the board as a reference during the lesson will be extremely helpful. It would be very helpful to copy the vocabulary list and hand it out to the students to read after the lesson.

Assign the two websites with virtual tours for homework prior to the lesson. This saves time during class and helps to introduce the students to the topics. You can have the web sites available to use during class and refer to as needed. When the students plot the data as part of the activity, the teacher should also have some data plotted as an example to put up on an overhead to facilitate discussion.

Use the “Me” Connection as the evaluation rather than the suggested written interpretations. This will allow for smooth flow of the lesson and also give the students another way to look at the comparisons.

Materials

- ❐ Copies of "*Lamellibrachia* Growth Rate Data Sheet" and "Growth Data Worksheet," one of each sheet for each student group

Audio/Visual Materials

None

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Groups of four students

Maximum Number of Students

20

Key Words

Cold seeps
Methane hydrate ice
Chemosynthesis
Brine pool
Vestimentifera
Trophosome
Growth rate
Longevity

Background Information

One of the major scientific discoveries of the last 100 years is the presence of extensive deep-sea communities that do not depend upon sunlight as their primary source of energy. Instead, these communities derive their energy from chemicals through a process called chemosynthesis (in contrast to photosynthesis in which sunlight is the basic energy source). Some chemosynthetic communities have been found near underwater volcanic hot springs called hydrothermal vents, which usually occur along ridges separating the Earth's tectonic plates. Hydrogen sulfide is abundant in the water erupting from hydrothermal vents, and is used by chemosynthetic bacteria that are the base of the vent community food web. These bacteria obtain energy by oxidizing hydrogen sulfide to sulfur:

$CO_2 + 4H_2S + O_2 > CH_2O + 4S + 3H_2O$

(carbon dioxide plus hydrogen sulfide plus oxygen yields organic matter, sulfur, and water). Visit http://www.pmel.noaa.gov/vents/home.html for more information and activities on hydrothermal vent communities.

Other deep sea chemosynthetic communities are found in areas where hydrocarbon gases (often methane and hydrogen sulfide) and oil seep out of sediments. These areas, known as cold seeps, are commonly found along continental margins, and (like hydrothermal vents) are home to many species of organisms that have not been found anywhere else on Earth. Typical features of communities that have been studied so far include mounds of frozen crystals of methane and water called methane hydrate ice, that are home to polychaete worms. Brine pools, containing water four times saltier than normal seawater, have also been found. Researchers often find dead fish floating in the brine pool, apparently killed by the high salinity.

As is the case with hydrothermal vents, chemosynthetic bacteria are also the base of the food web in cold seep communities. Bacteria may form thick bacterial mats, or may live in close association with other organisms.

One of the most conspicuous associations exists between chemosynthetic bacteria and large tubeworms that belong to the group Vestimentifera (formerly classified within the phylum Pogonophora; recently Pogonophora and Vestimentifera have been included in the phylum Annelida). Pogonophora means "beard bearing," and refers to the fact that many species in this phylum have one or more tentacles at their anterior end. Tentacles of vestimentiferans are bright red because they contain hemoglobin (like our own red blood cells). Vestimentiferans can grow to more than 10 feet long, sometimes in clusters of millions of individuals, and are believed to live for more than 100 years. They do not have a mouth, stomach, or gut. Instead, they have a large organ called a trophosome, that contains chemosynthetic bacteria. Hemoglobin in the tubeworm's blood transports hydrogen sulfide and oxygen to bacteria living in the trophosome. The bacteria produce organic molecules that provide nutrition to the tubeworm. Similar relationships are found in clams and mussels that have chemosynthetic bacteria living in their gills. A variety of other organisms are also found in cold seep communities, and probably use tubeworms, mussels, and bacterial mats as sources of food. These include snails, eels, sea stars, crabs, isopods, sea cucumbers, and fishes. Specific relationships between these organisms have not been well-studied.

While there are many similarities between biological communities associated with hydrothermal vents and cold-seeps, there are also some important differences. One of these is that the physical environment of vent communities can change dramatically over a short period of time. Highly acidic water as hot as 400°C may suddenly erupt, accompanied by large amounts of toxic hydrogen sulfide. Vent organisms adapted to this rapidly changing environment often have growth rates that are much higher than those seen among organisms living in other deep-sea communities.

Things are different in cold-seep communities, where the slow, steady release of methane and other hydrocarbon compounds provides a much more consistent environment. Yet, some species characteristic of cold-seep communities are quite similar to species found in vent communities. Tubeworms, for example, are abundant in both communities and have similar symbiotic relationships with chemosynthetic bacteria. Tubeworms in vent communities are among the fastest-growing invertebrates on the planet, and reach a large size in relatively few years. Do tubeworms in cold seep communities also have rapid growth rates? How old are the largest tubeworms in cold seep communities? These questions are the subject of this activity.

Learning Procedure

1. Lead a discussion of deep-sea chemosynthetic communities. Contrast chemosynthesis with photosynthesis. Point out that there are a variety of chemical reactions that can provide energy for chemosynthesis. Visit http://www.bio.psu.edu/cold_seeps for a virtual tour of a cold seep community, and http://www.bio.psu.edu/hotvents for a virtual tour of a hydrothermal vent community.

2. Distribute a "*Lamellibrachia* Growth Rate Data Sheet" to each student group. Explain that these are results taken from studies on

vestimentiferans at two cold-seep sites in the Gulf of Mexico. In these studies, the worms, outer tube was marked with a blue stain. After one or more years, stained individuals were collected, and new tube growth was measured as the length of the unstained segment of the tube between the stain mark and the end of the worm. Have each group plot growth rate (y-axis) as a function of length of the worm (x-axis). Students should draw a curve that passes through or near as many data points as possible.

3. Discuss the plotted data. These graphs show that growth rate of the tubeworms becomes slower as the size of the animals increases. This is common among most species of animals.

4. Next we want to estimate the age of the largest animals. The researchers did this by fitting a curvilinear regression line to the data, then integrating the growth equation over the interval [0, tube length]. An alternative, but less precise, approach can be used to estimate an approximate age. This approach involves breaking an animal's growth history into a series of intervals, determining how long it took to grow through each interval, then adding these individual growth times together to arrive at an approximate age (integration is based on a similar approach for a nearly infinite number of intervals). The curve drawn in Step #2 represents the growth history of an "average" tubeworm, based on growth data from 35 individual tubeworms. This curve will be used to estimate the age of a tubeworm 200 cm long.

   Distribute one "Growth Data Worksheet" to each group. The first interval to be considered is 0 - 10 cm. Have students use their plots from Step #2 to find the predicted growth rates (in cm per year) at size = 0 cm and size = 10 cm. Tell students to find the average of these two numbers, and assume that this average represents how fast the animal was growing between the sizes of 0 and 10 cm. Now, calculate how long (in years) it would take to grow 10 cm by dividing 10 cm by the average growth rate (cm/yr). Round answers to the nearest tenth of a year, and enter the result in the last column of the worksheet.

   Repeat this process for the remaining intervals (10 - 20 cm, 20 - 30 cm ....190 - 200 cm), finding the average growth rate for the interval, calculating how long it would take the animal to grow 10 cm, and entering the result in the last column of the worksheet.

   Add all of the entries in the last column of the worksheet to find the total time required to grow through all intervals from 0 through 200 cm. This sum is the estimated age of a tubeworm whose length is 200 cm.

5. Have each group present their results. Each group will probably be somewhat different due to the need to estimate intermediate points on the graphs. The overall trend, however, should show that a 200 cm tubeworm from the sites studied would be over 200 years old. Discuss these results, asking students whether it is reasonable to suppose that tubeworms could be this old. Why not; after all, how much do we really know about

average life expectancy among deep-sea organisms? Ask what factors might contribute to this longevity (such as a very stable environment and absence of many predators or competitors because of extreme conditions to which these animals are especially well-adapted). Is it likely that other species could also be relatively old, compared to similar species in other communities? Again, why not, since the factors that might help tubeworms live for a long time could also help other species do the same. Ask students why there should be such a striking difference in growth rates between tubeworms at hydrothermal vents and cold seeps (vent communities exist in very dynamic conditions, and things may change dramatically at any time; cold seep communities are based on slow leakage of hydrocarbon materials from beneath the sea floor, and probably do not experience much change over very long periods of time.)

The BRIDGE Connection

www.vims.edu/bridge/vents.html

The "Me" Connection

Have students write a short essay contrasting life in two communities. The first community exists in a remote valley where weather patterns and local physical conditions combine to produce a very stable and livable climate that remains virtually unchanged from year to year. The other community exists in a region that frequently experiences significant volcanic activity, including eruptions of poisonous gases and superheated air. Students may assume that the first community offers unusually long life-spans to individuals living there, while the second community offers unusually rapid growth and maturation of individuals (couples typically have their first child at the age of 7), as well as the prospect of sudden and unpleasant death at any time.

Connections to Other Subjects

English/Language Arts, Earth Science

Evaluation

Have students prepare individual written interpretations of their results prior to oral presentations in Step #5.

Extensions

Have students investigate growth studies in other ocean communities, and develop hypothesis for why growth and longevity vary among these communities.

Resources

http://oceanexplorer.noaa.gov – Follow the Gulf of Mexico Expedition daily as documentaries and discoveries are posted each day for your classroom use.

http://www.bio.psu.edu/People/Faculty?Fisher/thome.htm – Web site for the principal investigator on the Gulf of Mexico expedition

http://www.rps.psu.edu/deep/ – Notes from another expedition exploring deep-sea communities

http://www.ridge.oce.orst.edu/links/edlinks.html – Links to other deep ocean exploration web sites

http://www-ocean.tamu.edu/education/oceanworld/resources/ – Links to other ocean-related web sites

Paull, C.K., B. Hecker, C. Commeau, R.P. Feeman-Lynde, C. Nuemann, W.P. Corso, G. Golubic, J. Hook, E. Sikes, and J. Curray. 1984. Biological communities at Florida Escarpment resemble hydrothermal vent communities. Science 226:965-967 – Early report on cold seep communities.

Bergquist, D. C., F. M. Williams, and C. R. Fisher. 2000. Longevity record for deep-sea invertebrate. Nature 403:499-500. – Technical journal article upon which this activity is based.

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Content Standard B: Physical Science

- Chemical reactions

Content Standard C: Live Science

- Interdependence of organisms

Activity developed by Mel Goodwin, PhD, The Harmony Project, Charleston, SC

Lamellibrachia Growth Rate Data Sheet

Length of Tubeworm (cm)	Growth Rate (cm per year)
5	4.75
10	4.25
10	4.75
10	3.75
20	4.25
20	3.60
20	3.00
30	3.20
30	2.80
40	2.75
40	3.00
50	2.00
50	2.75
50	2.40
60	2.00
70	2.25
70	1.25
80	1.50
90	1.75
90	0.75
100	1.25
110	1.00
120	0.75
130	0.75
130	1.00
130	0.50
150	0.50
150	0.75
150	0.25
170	0.50
170	0.10
180	0.70
180	0.10
200	0.05
200	0.45

Growth Data Worksheet

Growth Interval (cm)	Growth Rate at Beginning of Interval (cm/yr)	Growth Rate at End of Interval (cm/yr)	Average Growth Rate (cm/yr)	Time to Grow 10 cm (yr)
0 – 10				
10 – 20				
20 – 30				
30 – 40				
40 – 50				
50 – 60				
60 – 70				
70 – 80				
80 – 90				
90 – 100				
100 – 110				
110 – 120				

120 – 130

130 – 140

140 – 150

150 – 160

160 – 170

170 – 180

180 – 190

190 – 200

TOTAL TIME TO REACH 200 CM ---

Notes/Thoughts/Inspirations